CALIFORNIA CRUDE OIL PRODUCTION AND IMPORTS

STAFF PAPER

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APRIL 2006
CEC-600-2006-006

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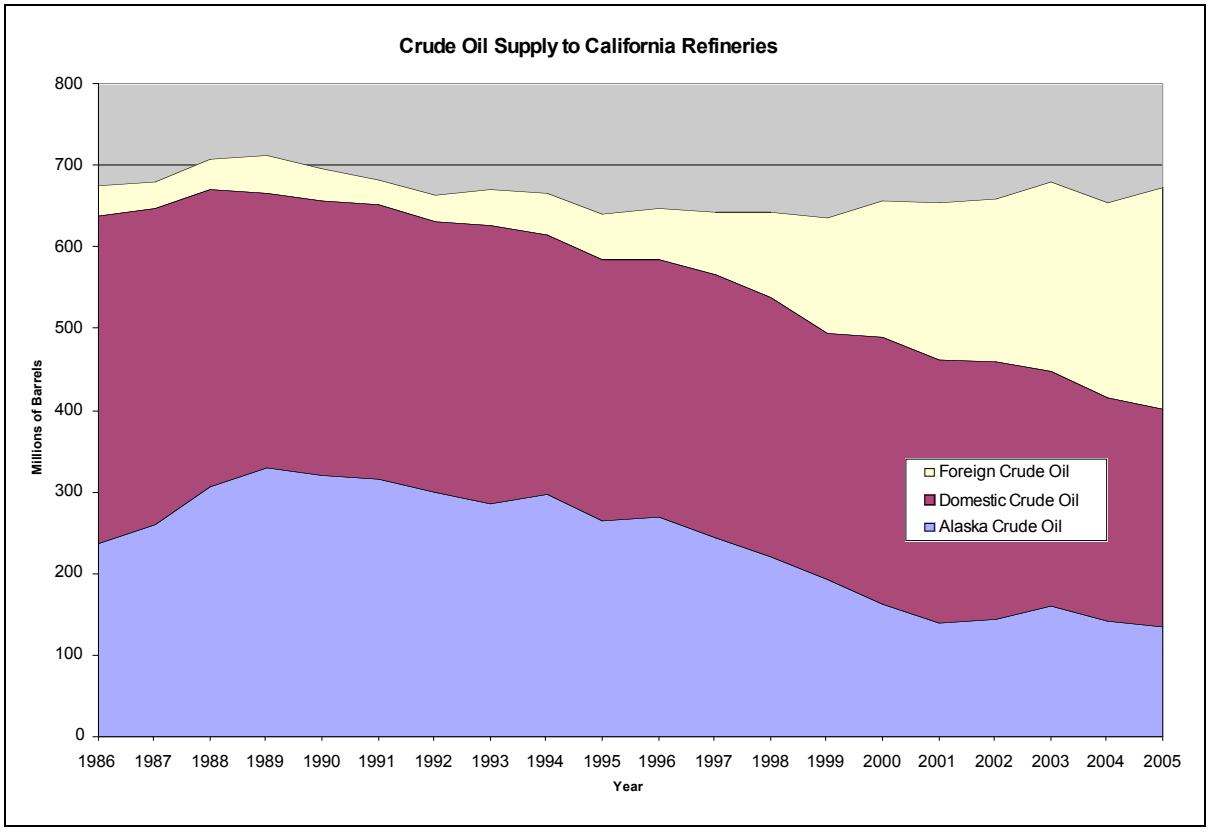
Introduction

Californians consume nearly 44 million gallons of gasoline and 10 million gallons of diesel every day.[1] California refineries produce these fuels and other products from crude oil and blending components. Transportation fuel production in California depends on the availability and quality of the crude oils used by refineries in the state. Figure 1 shows the average annual refinery receipts of crude oil from 1986 to 2005. The supply of crude oil to California refineries has changed substantially in the last 10 years. Most notably, receipts of foreign crude oil have increased as production sources from California and Alaska have continued to decline.

Figure 1



Source: Petroleum Industry Information Reporting Act

Historically, California has been relatively self-reliant in petroleum supplies. However, crude oil production in California has decreased by 23 percent since 1996.[2] This decline of supply in the state has increased reliance on foreign and domestic imports. Starting in 1994, California refineries received more imported

crude oil than in-state sources. In 2005, California crude oil accounted for approximately 37 percent of the total receipts.

The quality of the crude oil used by the refinery in conjunction with the complexity of processing units dictates the percentages of products produced. For example, lower quality crude oil is more difficult to refine into lighter products, such as motor and aviation gasoline. Refineries have minimum crude oil quality requirements that are determined by the processing units in the plant.

This paper presents information on crude oil characteristics, California crude oil production trends, and their possible impact on future transportation fuel production.

Crude Oil Characteristics

The quality of crude oil is determined by a number of characteristics that affect the proportions of transportation fuels and petroleum products produced when the oil is refined. The two most common measurements of crude oil quality are the specific gravity (which is measured in degrees) and the sulfur content of the oil. Acid content is also a factor in determining the corrosive properties of the crude oil entering the refinery.

Specific Gravity

The specific gravity is typically measured using the American Petroleum Institute (API) standard or the API gravity of the crude oil. The API gravity is the measure of the weight of crude oil in relation to the weight of water (water has an API gravity of 10 degrees). Crude oil is characterized as heavy, intermediate, or light with respect to its API gravity.

- Heavy Crude: Crude oils with API gravity of 18 degrees or less is characterized as heavy. The oil is viscous and resistant to flow, and tends to have a lower proportion of volatile components. Fifty one percent of California crude oil has an average API of 18 degrees or less.

- Intermediate Crude: Crude oils with an API greater than 18 and less than 36 degrees are referred to as intermediate. Forty eight percent of California crude oil has an average API between 18 and 36 degrees.

- Light Crude: Crude oils with an API gravity of 36 degrees or greater. Light crude oil produces a higher percentage of lighter, higher priced premium products.

Sulfur Content

Crude oil is defined as “sweet” if the sulfur content is 0.5 percent or less by weight and “sour” if the sulfur content is greater than 1.0 percent. Sulfur compounds in crude oil are chemically bonded to hydrocarbon molecules in the oil. Additional equipment in the refinery is required to remove the sulfur from crude oil, intermediate hydrocarbon feedstocks, and finished products. Transportation fuel specifications require extremely low sulfur contents, usually less than 80 parts per million (ppm).

Acid Content

Another characteristic of crude oil is the total acid number (TAN). The TAN represents a composite of acids present in the oil and is measured in milligrams (mg). A TAN number greater than 0.5 mg is considered high.[3] As an example, Wilmington and Kern crude oil have a TAN ranging from 2.2 to 3.2 mg, respectively.[4] However, some acids are relatively inert. Thus, the TAN number does not always represent the corrosive properties of the crude oil. Further, different acids will react at different temperatures – making it difficult to pinpoint the processing units within the refinery that will be affected by a particular high TAN crude oil. Nonetheless, high TAN crude oils contain naphthenic acids, a broad group of organic acids that are usually composed of carboxylic acid compounds. These acids corrode the distillation unit in the refinery and form sludge and gum which can block pipelines and pumps entering the refinery.[5]

The impact of corrosive, high TAN, crude oils can be overcome by blending higher and lower TAN oils, installing or retrofitting equipment with anticorrosive materials, or by developing low temperature catalytic decarboxylation processes using metal catalysts such as copper. Many California refineries already process high TAN crude. High TAN oils are sold on the market at a discount compared to higher quality crude oils.

High TAN oils account for an increasing percentage of the global crude oil market. Crude oil with a TAN greater than 1.0 mg increased in the world market from 7.5 percent in 1998 to 9.5 percent in 2003.[6]

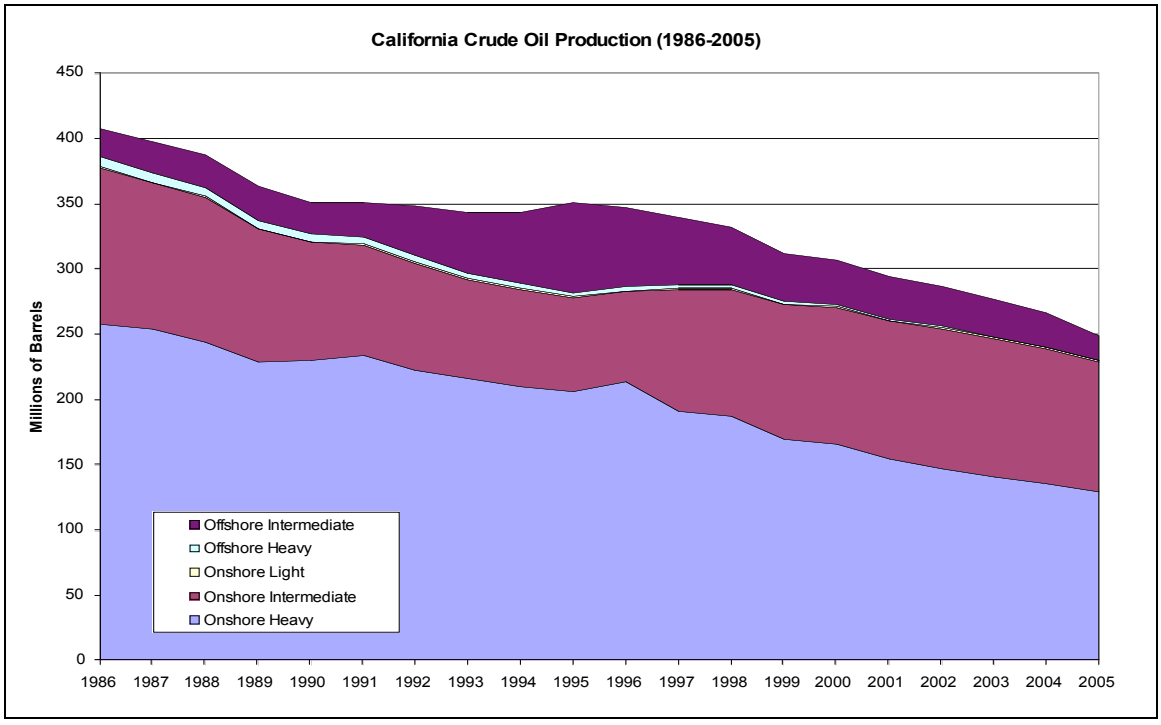
California Crude Oil Production

The discovery of oil in Kern County in the late 19th century heralded a long history of oil production in California. At the turn of the 20th century, crude oil was valued primarily for the heavier products and refining was oriented towards the production of heating oil and lubricants. In the early 1900s, with growing automobile use, gasoline became a more important commodity.

California is currently ranked fourth in the nation among oil producing states, behind Louisiana, Texas, and Alaska, respectively. Crude oil production in California averaged 731,150 barrels per day in 2004, a decline of 4.7 percent from 2003. Statewide oil production has declined to levels not seen since 1943.[7]

Figure 2 shows California onshore and offshore crude oil production over the last 20 years. The production of heavy, intermediate, and light crude oil production are broken out for onshore and offshore (or Outer Continental Shelf [OCS]) areas.

Figure 2



Sources: California Department of Conservation, Minerals Management Service

Production peaked in California in 1983. Production has declined at an average rate of 2.4 percent per year in the last 10 years.

Figure 2 shows a constant decline in onshore heavy crude oil production from 1986 through 2005 of 6.8 million barrels per year, or approximately 3.5 percent per year. Intermediate onshore oil production remained relatively flat. Offshore crude oil production peaked at 72 million barrels in 1995 and has declined by around 4.3 million barrels per year - or 10.2 percent per year - from 1995 through 2004.

The three major regions of California crude oil production are Kern County, the Los Angeles Basin, and the Outer Continental Shelf (OCS).

- **Kern County:** In 2004, oil from Kern County accounted for 77 percent of California's total onshore production and over 69 percent of the state's total oil production.[8] Approximately 58 percent of the crude oil has an API of 18 degrees or less. The Kern River oil field, located in the eastern San Joaquin Valley, accounts for approximately 24 percent of Kern County oil. Kern River oil is characteristically heavy and sour with an API of 13.4 degrees and a sulfur content of 1.2 percent.[9]

- **Los Angeles Basin:** The Los Angeles Basin is a sedimentary plain extending from central Los Angeles south through the Long Beach area. The two largest fields by area in this region are the Wilmington and the Huntington Beach fields with average APIs of 17.1 and 19.4 degrees, and average sulfur contents of 1.7 and 2.0 percent, respectively.

- **Outer Continental Shelf:**[10] The Federal Minerals Management Service oversees crude oil rigs located three nautical miles or greater from the coast. The OCS rigs accounted for 10.2 percent of the total California production in 2004. Many of these rigs are leased to commercial companies with pipelines extending to onshore processing facilities. The quality of OCS crude oil varies by field. Both sweet and sour OCS crude oils have API gravities ranging from 14 to 38 degrees.[11] Intermediate crude oil with an API gravity between 18 and 36 degrees accounted for 96.6 percent of the OCS production in 2004.

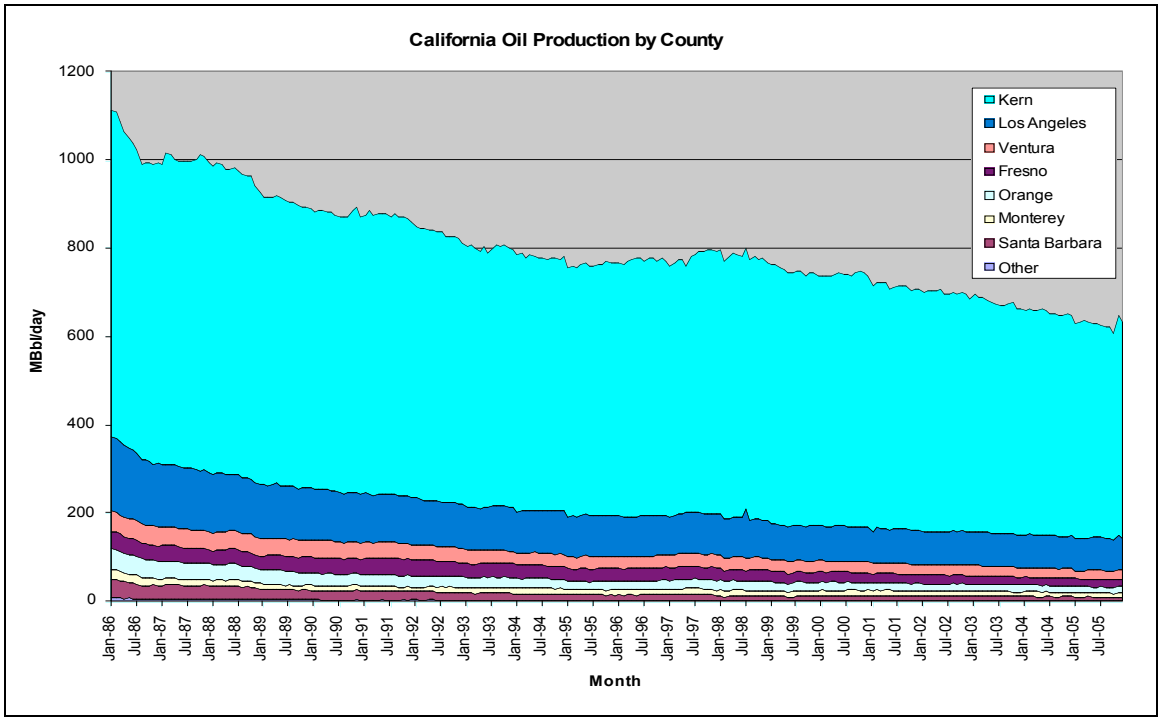
Table 1 shows an assay of selected California crude oils.[12] The table provides the percentages of 2005 production to show the relative importance of the field. The distillation breakdown of each crude oil provides a general guideline of the refining product suite that would result after the initial crude distillation has been completed. The actual ratio of finished refined products will vary depending on the complexity of the refinery. Note that unrecoverable gas losses occur in the assay, resulting in distillation product summations of less than 100 percent.

Table 1

County	Field	Percent of 2005 Production	API Gravity & Sulfur	Distillation breakdown (percent per volume)			
				Total Gasoline & Naptha	Middle Distillates	Residuum	Lubes
Kern & San Luis Obispo	Midway Sunset	18.47%	12.6, 1.6%	0.00%	12.00%	50.30%	34.80%
Kern	Kern River	14.36%	13.3, 1.1%	0.00%	15.80%	56.10%	28.10%
Kern	Elk Hills	7.91%	34.6, 0.8%	34.30%	23.30%	25.00%	15.90%
Los Angeles	Wilmington	6.49%	17.1, 1.7%	9.50%	18.20%	52.80%	19.40%
Kern	Lost Hills	4.96%	18.4, 1.0%	7.60%	23.50%	42.70%	23.20%
Ventura	Ventura	1.75%	30.2, 1.0%	30.20%	20.80%	31.30%	16.30%
Kern	Belridge N. Lt.	1.63%	31.3, 0.3%	25.70%	25.70%	26.30%	20.90%
Monterey	San Ardo	1.52%	12.2, 2.3%	2.10%	14.50%	62.50%	20.50%
Los Angeles	Inglewood	1.24%	21.0, 1.8%	12.90%	27.60%	39.10%	19.40%
Orange	Huntington Beach	1.07%	19.4, 2.0%	12.00%	19.70%	48.90%	19.40%
Los Angeles	Long Beach	0.65%	25.0, 1.3%	18.90%	23.10%	40.60%	17.40%
Kern	Mount Poso	0.26%	16.0, 0.7%	0.00%	13.40%	52.00%	34.00%

Figure 3 shows the onshore production by county.

Figure 3



Source: Dept. of Conservation

California commonly uses Thermally Enhanced Oil Recovery (TEOR) techniques to help maintain crude oil production, because heavy, viscous crude oil requires heating to move the oil to the pump. Direct injection steaming and intermittent steaming are two types of TEOR. California crude oil production is also enhanced by injection of water (water flooding) and even carbon dioxide (CO_2) to help maintain sufficient pressure in the crude oil field. In the absence of more aggressive use of TEOR, California's crude oil production is expected to continue to decline at a rate of 3.5 percent per year through 2019.[13]

Well activity provides an indication of potential production in the state. In 2004, drilling increased to 2,451 wells, a 6.7 percent increase from 2003. The number of plugged wells decreased to 2,039 from 2,501 in 2003. Drilling and plugging activities in the state have fluctuated by more than 900 wells from year to year; however, the general trend is relatively flat.

Alaska North Slope Crude Oil

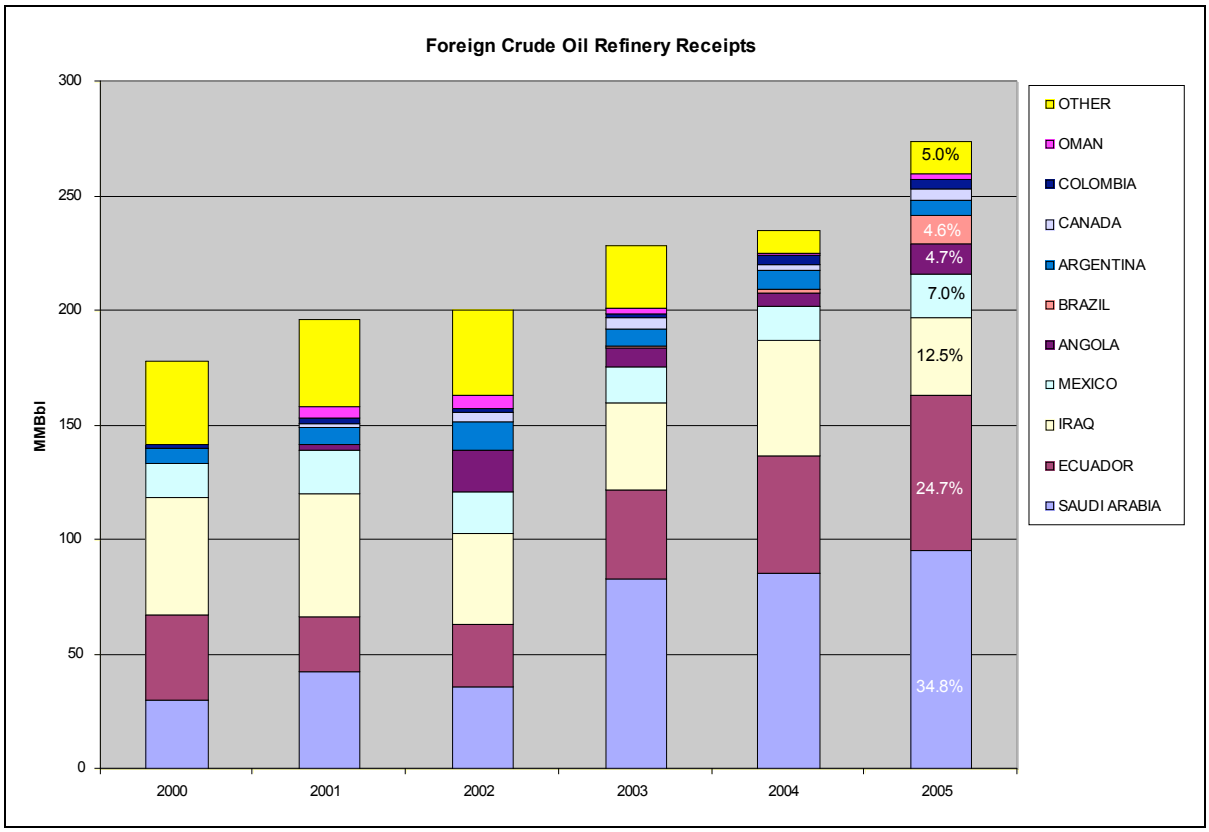
In 2005, California imported 21 percent of its total crude oil supply from Alaska. Oil fields in Alaska's North Slope produce a wide range of crude oils. API gravities from different fields range from 22 to 40 degrees. Alaskan refineries located along the Trans Alaska Pipeline System (TAPS) "top" the crude oil to produce light petroleum products and return residual products to the line. The resulting blended crude oil stream is referred to as Alaska North Slope oil (ANS). The ANS is an intermediate sour crude with an average API gravity of 29-29.5 degrees and sulfur content of 1.1 percent.

Like California crude oils, ANS production has been declining in the last 10 years. The average annual rate of decline in ANS production is approximately 5 percent per year.

Foreign Crude Oil Imports

The majority of crude oil imports to California are from the Middle East, Central America, and South America. Figure 4 shows a six year history of imports by region.

Figure 4



Source: Energy Information Administration

Crude oil imported from countries with volatile political and social structures leaves California vulnerable to changing world events. For example, attacks on Nigerian oil industry personnel led to the recent shutdown of nearly 9 percent of Nigeria's total oil production, which could impact global oil availability and increase feedstock costs for California refineries. Also, the growing political tension between the U.S. and Iranian governments over Iran's nuclear program could impact California's crude oil supply if the U.S. decides to impose sanctions on Iran.

Table 2 shows approximate crude oil characteristics for several imported crude oils.[14]

Table 2

Crude source	Paraffins Percent Volume)	Aromatics (Percent Volume)	Naphthenes (Percent Volume)	Sulfur (Percent Weight)	API gravity (Approx.)	Napht. yield (Percent Volume)	Octane No. (Typical)
Nigerian - Light	37	9	54	0.2	36	28	60
Saudi - Light	63	19	18	2	34	22	40
Saudi - Heavy	60	15	25	2.1	28	23	35
Venezuela - Light	35	12	53	2.3	30	2	60
Venezuela - Heavy	52	14	34	1.5	24	18	50
North Sea - Brent	50	16	34	0.4	37	31	50

Source: Office of Safety and Health Administration

The API gravity of refinery imports reported to the Energy Commission through the Petroleum Industry Information Reporting Act (PIIRA)[15] show an increase of 0.27 API per year from 1996 to 2005 for larger refineries. Smaller refineries show a relatively flat API during the same time period, predominantly because these smaller refineries solely use crude oil from California sources.[16]

Crude Oil Supply and Distribution to California Refineries

The distribution of domestic and imported crude oils is dependent on the port, pipeline, truck, and rail transport infrastructure within the state. All ANS and imported crude oils enter the state through ports in Los Angeles, Long Beach, and the Bay Area.

Water depth limits access to Bay Area ports. The water depth of these ports is typically between 32 to 45 feet, which is too shallow for large crude oil carriers. As an example, a carrier with a capacity of 1.3 million barrels will require a minimum water depth of at least 66 feet. For shallower ports, large vessels will anchor in a designated zone outside of the ports and smaller barges will transfer oil to the ports, a practice referred to as “lightering.” This practice adds to the delivery cost of crude oil to the refinery and increases the risk of accidental release of crude oil into the environment.

Another complication for the Bay Area ports is silting in the bays. Dredging of the bays is controversial in that habitat is disturbed and dredged material must be disposed of in an environmentally sound manner. For example, approximately 4 million cubic yards of sediment are dredged from the Central and South Bay per year.[17]

Pipeline networks tie the San Joaquin Valley crude oil production with refineries in both the Los Angeles and the Bay Area. Figure 5 shows the major crude oil pipelines in California.

Figure 5

Source: California Energy Commission

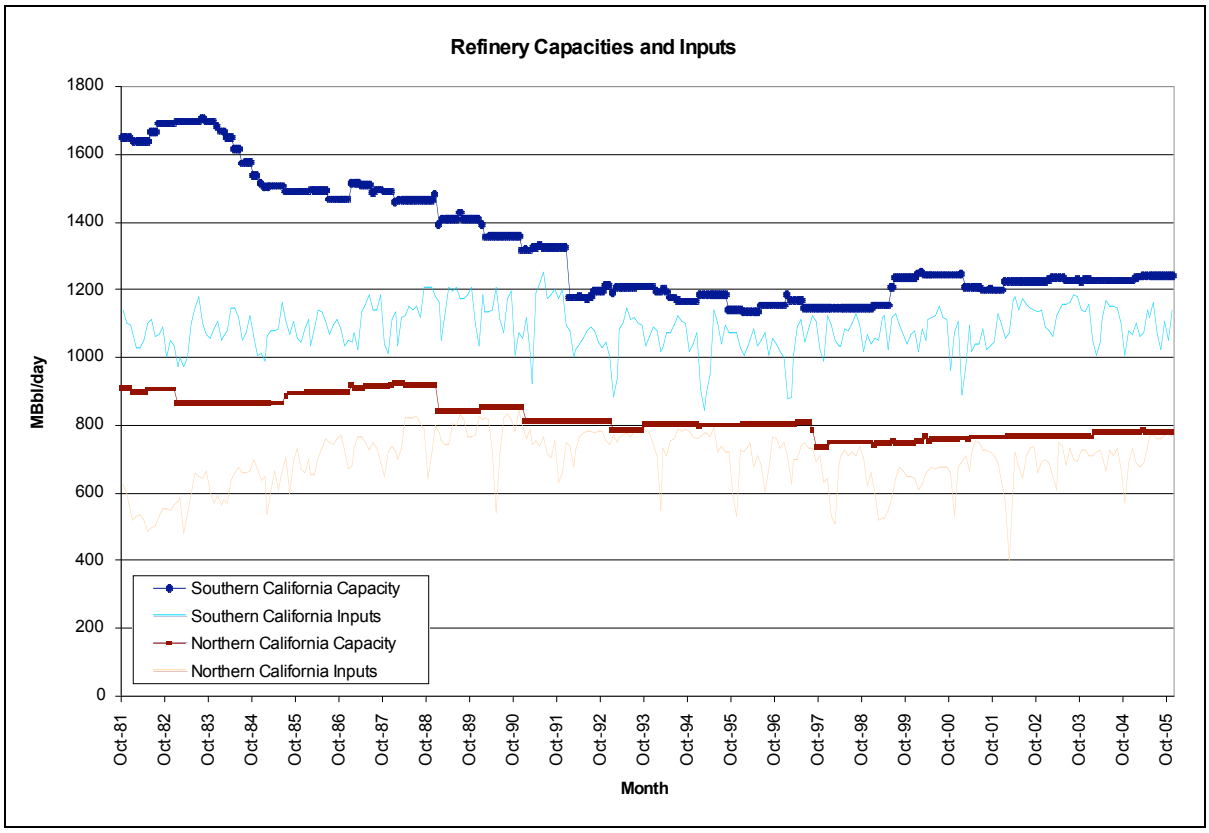
In California, 51 percent of the crude oil produced in the state is heavy crude. The transport of heavy crude through pipelines is complicated by the viscosity and inertia of the oil. Thus, some of the crude oil pipeline systems throughout the state require external heating. Booster stations are placed at intervals on the line where heating and/or pumping units facilitate the flow of the crude through the line. The proximity of booster stations is determined by the viscosity of the crude and by the average heat loss from the pipes from ambient weather conditions. Heavier crude oils are also blended with lighter crude oils to reduce viscosity, allowing transportation through pipelines without any heating.

Inland California crude oils are typically first piped to local refineries (Bakersfield and Santa Maria) because they are nearby and do not have port access. The balance of inland crude oils are piped to Northern and Southern California refineries.

Refinery Operations

In the last two decades, California refineries have been running increasingly closer to capacity levels. Figure 6 shows the total crude oil throughput refining capacity and the throughput oil inputs to the refinery by area.

Figure 6



Source: Petroleum Industry Information Reporting Act

The steady decline in refinery capacity during the 1980s and early 1990s is followed by a noticeable creep upward in the late 1990s and early 2000s. With refinery creep and greater import capabilities in the Los Angeles area, southern refineries are less constrained than their Bay Area and Central California counterparts. Southern California refineries also show an increasing level of crude oil imports.

Refinery operations must also consider recent diesel regulations by the U.S. Environmental Protection Agency (EPA) and the California Air Resources

Board (ARB). The EPA regulation lowers the allowable amount of sulfur in on-road diesel fuel from less than 500 parts per million (ppm) to less than 15 ppm. This requirement will take effect on June 1, 2006. The sulfur content and API gravity of crude oil input to the refinery in conjunction with the complexity of process units will affect the quantity of ultra-low sulfur diesel produced by the facility.

The hydrocracking and hydrotreater units remove sulfur within the refinery. Hydrocracking units break hydrocarbon molecules into lighter compounds in the presence of hydrogen. Hydrotreatment involves the chemical reaction of hydrocarbon compounds with hydrogen in the presence of a catalyst such as cobalt or alumina.[18]

Refineries throughout the U.S. are currently upgrading their desulfurization processes in order to meet the new diesel sulfur standards. This upgrade typically involves techniques such as changing the catalyst in the hydrotreater or installing booster pumps to force more feedstock through the unit. Both hydrocrackers and hydrotreaters also remove heavy metals and aromatics from the feedstock. This is particularly important in California where lower aromatic standards will be required along with the new ultra low sulfur diesel standards.

Findings

- The declining crude oil production in South-Central California has resulted in higher crude oil costs because of reliance on higher priced imported crude oils.

- Pipeline utilization rates are decreasing and the procurement of crude oil to inland refineries is becoming increasingly difficult as local supplies decline.

Current and Future Work

Additional reporting requirements in the Energy Commission's new petroleum industry data collection regulations will greatly enhance the agency's understanding of crude oil and finished product movements within the state. The addition of port, terminal, and pipeline information will provide the details needed to track infrastructure use within the state. This additional information will be essential in: assessing near-term petroleum infrastructure demand shifts, reviewing project expansion plans, and completing contingency studies.

Research and analysis should focus, in particular, on the following areas:

- Crude oil quality: The growing dependence of California refineries on imported crude oils requires a more detailed look at the characteristics of overseas crude oils entering ports in the state. The general trend of

international crude oil production reflects an increase in low API, high sulfur content crude oil. However, overall API gravity in California refineries has increased primarily from the decline in heavy California crude oil production. The examination of supply information from secondary sources and from PIIRA reporting data will help to identify areas of constraint in the state.

- Total Acid Number (TAN): The increase in world production of heavy, sour, and high TAN crude oils will impact California refineries. An assessment of the crude oil processing capabilities of California refineries is needed to understand the potential implications of future changes in the global crude oil market.

- Crude oil pipelines: The decrease in crude oil production in the state has led to changes in the utilization rates of some crude oil pipelines. Modifying current pipeline systems and/or making new investments in distribution infrastructure may be necessary to provide more stable sources of crude oil for refineries without port access.

Endnotes

[1] California State Board of Equalization data for 2004. Taxable gasoline figures amounted to an average of 43.5 million gallons per day, while taxable diesel fuel sales figures have been adjusted upward to reflect an estimated 22 percent distribution of exempt and refund diesel sales that are excluded from their taxable gallons.

[2] Based on data compiled from the California Department of Conservation database production files, http://www.conservation.ca.gov/DOG/prod_injection_db/index.htm and MMS Offshore data, http://www.gomr.mms.gov/homepg/pubinfo/pacificfreeasci/product/pacificfreeprod.html.

[3] http://rru.worldbank.org/Documents/publicpolicyjournal/275-bacon-tordo.pdf.

[4] http://www.pacificenergypier400.info/pdfs/CRUDESUP/PACIFICP.PDF.

[5] http://www.ornl.gov/sci/fossil/Publications/RECENT%20PUBS/DDSum2003.pdf.

[6] Anne Shafizadeh, Gregg McAteer, and John Sigmon, *High-Acid Crudes*, paper presented at Crude Oil Quality Group meeting, New Orleans, January 30, 2003, [http://www.coqg.org/20030130special.asp]

[7] ftp://ftp.consrv.ca.gov/pub/oil/annual_reports/2004/PR06_Annual_2004.pdf.

[8] California Department of Conservation database production files, http://www.conservation.ca.gov/DOG/prod_injection_db/index.htm.

[9] Van Vector, Samuel, *Pricing Royalty Crude Oil*, http://www.econ.com/apijan00.pdf.

[10] MMS data for 2004 is approximately 95 percent complete. December 2005 data not yet posted.

[11] Jokuty, P.; Whiticar, S.; Wang, Z.; Fieldhouse, B.; and Fingas, M.; *A Catalogue of Crude Oil and Oil Product Properties for the Pacific Region,* 264p 1999.

[12] http://www.econ.com/apijan00.pdf.

[13] http://www.energy.ca.gov/2005_energypolicy/documents/2005-0516_workshop/presentations/Baker%20&%20OBrien%20Presentation%205-16-05.pdf.

[14] OSHA Technical Manual – Section IV: Chapter 2, http://www.osha-slc.gov/dts/osta/otm/otm_iv/otm_iv_2.html.

[15] PIIRA: the Petroleum Industry Information Reporting Act, Public Resources Code 25350 et seq.

[16] Large and small refineries are defined here as refineries with crude oil receipts in 2005 greater than or less than 5 percent of the total for the state, respectively.

[17] http://www.spn.usace.army.mil/ltms/chapter2.pdf.

[18] http://www.bp.com/genericarticle.do?categoryId=2013107&contentId=2019673.